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FURTHER DATA ON THE STRATIGRAPHIC POSITION OF THE LANCE FORMATION ("CERATOPS BEDS")[1]

F. H. KNOWLTON

In June, 1909, I published a paper entitled: "The Stratigraphic Relations and Paleontology of the 'Hell Creek Beds,' 'Ceratops Beds,' and Equivalents, and Their Reference to the Fort Union Formation."[2] In that paper, as suggested by the title, the conclusion was reached that the beds considered—namely, the "Hell Creek beds," "Ceratops beds," "somber beds," and "Laramie" of many writers—are "stratigraphically, structurally, and paleontologically inseparable from the Fort Union, and are Eocene in age."

It was expected that this somewhat radical innovation would be received with a storm of protest, especially by the vertebrate paleontologists, but so far as known to the author only three papers have since appeared which deal specifically with the position of the "Ceratops beds." These comprise two papers by Dr. T. W. Stanton and one by Dr. O. P. Hay.

As two field seasons have intervened since the publication of my paper, during which important data were secured confirming the position there assigned the Lance formation,[3] it seems opportune to present the case as it now stands. The areas in which these observations were made are in the main in Eastern Wyoming and Eastern Montana and adjacent portions of North and South Dakota.

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[1] Published with the permission of the Director of the U.S. Geological Survey.

[2] *Proc. Wash. Acad. Sci.*, XI (1909), 179–238.

[3] The name *Lance formation* has been formally adopted by the U.S. Geological Survey in place of the term "Lance Creek beds" or "Ceratops beds." Wherever *Lance formation* is employed in the following paper it is to be understood as including "Lance Creek beds," "Ceratops beds," "Hell Creek beds," "somber beds," "Lower Fort Union," and beds identified as "Laramie" by many writers.

NEAR THE MOUTH OF THE MEDICINE BOW RIVER, CARBON COUNTY, WYOMING

In the early nineties, when the late J. B. Hatcher was searching for new fields that might possibly supply additional material belonging to the then recently discovered group of horned dinosaurs (Ceratopsidae), he made an examination of the country lying along the North Platte River some twenty-five or thirty miles north of old Fort Fred Steele, in Carbon County, Wyoming. Hatcher observed fragmentary remains of dinosaurs at a point which he indicated[1] as "on the North Platte River opposite the mouth of the Medicine Bow River." As the dinosaurian remains were neither abundant nor well preserved, the country was not again visited until 1906, when a party from the United States Geological Survey, under the direction of Mr. A. C. Veatch, was engaged in investigating the coal resources of the so-called Carbon County coal-field. Veatch[2] published an outline geological map on which was shown the areal distribution of the formations involved. From this map it appeared that strictly speaking a point "opposite the mouth of the Medicine Bow River" would fall within Veatch's so-called "Lower Laramie,"[3] which is there 6,500 feet in thickness. Unfortunately Veatch did not collect any dinosaurian remains and thus settle definitely their position in this section, but from residents of the region who had known of Hatcher's discoveries it was pretty clearly indicated that they came from a series of low bluffs about a mile up the North Platte River from a point opposite the mouth of the Medicine Bow, in beds belonging to Veatch's so-called "Upper Laramie," which are in part at least the equivalent of the "Ceratops beds" of Converse County. The question of the absolute stratigraphic position of these dinosaur-bearing beds was thus held in abeyance until the past season (1910), when Dr. A. C. Peale and the writer spent ten days in the region, during which we secured data which settled the matter definitely. Incidentally it may be mentioned that we were able to confirm in every particular Veatch's mapping of the formations in this vicinity.

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[1] *Am. Nat.*, XXX (1896), 118.

[2] *U.S. Geol. Surv.*, *Bull. 316* (1907), 244, Pl. XIV.

[3] The "Lower Laramie" of Veatch is the same as the Laramie of the Denver Basin of Colorado as shown by its stratigraphic position and contained fossils. See Veatch, *Jour. Geol.*, XV (1907), 526–49.

On the west side of the North Platte River, opposite the mouth of the Medicine Bow River, the bluff in the "Laramie" is about a mile back from the river. The beds, which consist of alternations of soft shales and beds of shaly brownish sandstones and numerous thin beds of coal, dip to the southeast at angles between 20° and 25°. From the bluff the surface slopes gently to the stream, and exhibits admirable exposures throughout. A very careful search was made of the "Lower Laramie" section, and although invertebrates pronounced by Dr. Stanton to be of "Laramie" age were found at numerous horizons, not a scrap of bone could be detected.

The contact between the "Lower Laramie" and "Upper Laramie" is very distinct and undoubtedly has been correctly placed by Veatch. There is a distinct change in the dip, apparently a slight change in the strike, and a marked change in the lithology between the lower and upper beds. The basal 300–400 feet of the beds above the line are composed of somber-colored soft sandstones and shales, often cross-bedded, with occasional small ironstone concretions, and in every way suggest the "Ceratops beds" to the northeast. Fragments of bone are scattered over the surface, and although no large pieces were secured at this particular point, enough was found to prove the presence of turtles, crocodiles, and dinosaurs. On the strike of these beds at a point about six miles southeast (T23N, R84W) we found in place about 300 feet above the base of the "Upper Laramie" beds a number of large vertebrae. These have been studied by Mr. C. W. Gilmore of the U.S. National Museum, and Mr. Barnum Brown of the American Museum of Natural History, and by both pronounced unqualifiedly to belong to *Triceratops*. It is not possible to fix with certainty the species to which these vertebrae belong, since the characters separating the species are drawn mainly from the skull, but Mr. Gilmore permits me to say that it is impossible to distinguish them from vertebrae of certain species from Converse County in which both skull and vertebrae are known. It is quite possible that the skull of the individual of which we secured the vertebrae could be recovered by more extended excavation than we were able to make with the implements at hand.

Since, with the exception of their occurrence in the post-Laramie formations of the Denver Basin, the remains of *Triceratops* have never been found outside the Lance formation, the finding of *Triceratops* at this point is of far-reaching importance. It shows that not only are the beds containing them *above* more than 6,000 feet of "Laramie" rocks (the basal portion of which is almost certainly of Fox Hills age), but also that they are separated from the "Laramie" ("Lower Laramie") by an unconformity, which, according to Veatch,[1] is profound and has involved the removal of perhaps as much as 20,000 feet of sediments. This would seem effectively to dispose of the contention that the Lance formation ("Ceratops beds") is the equivalent of the Laramie.

The Lance formation—for such it must now be called—along the North Platte River above (south of) the mouth of the Medicine Bow, passes virtually without known stratigraphic break into beds which some twenty-five miles to the south have yielded Fort Union flora, thus showing the similarity of this section with all other known sections in which both Lance formation and Fort Union are present.

About 25 feet below the horizon of the *Triceratops* vertebrae, in the area under discussion, we collected the following species of plants:

Sabal grandifolia? Newb.
Populus amblyrhyncha Ward
Viburnum marginatum Lesq.
Sapindus sp.
Sassafras? sp. (Same as an unnamed species from the "Ceratops beds" of Converse County, Wyo.)

The palm, which is identified with some doubt as *Sabal grandifolia*, has a longer rachis than is usual in this species but is otherwise indistinguishable. It was described originally from the Fort Union near the mouth of the Yellowstone, and has been found subsequently at many localities in Montana, Wyoming, and Colorado. The *Populus* above mentioned has not been found outside the Fort Union. *Viburnum marginatum* was described first from Black Buttes, Wyoming, and has since been found in many places, among them several localities in the Lance formation of the Dakotas. The form identified as *Sassafras?* is a peculiar leaf and is apparently the same as an unnamed form from the Lance formation of Converse County. This analysis shows that three of the five forms noted in this collection are found in the Lance formation.

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[1] *Am. Jour. Sci.*, XXIV (1907), 18.

About five miles south of the above-mentioned *Triceratops* locality the "Upper Laramie" crosses the North Platte and the exposures are excellent. At this point the "Upper Laramie" consists of a great thickness of massive beds of yellowish and whitish sandstone, with much cross-bedding and abrupt changes from one color to another. Several hundred feet above the exposed base of this section we obtained a small collection of plants which embraces some three or four species, all of which are identical with undescribed forms from the Lance formation of Montana and the Dakotas.

The evidence of the plants is thus seen to confirm that of the vertebrates in correlating these beds with the Lance formation of Converse County and other areas in Montana and the Dakotas.

THE OLD STANDING ROCK AND CHEYENNE RIVER INDIAN RESERVATIONS

On the west side of the Missouri River, and lying between the Cannonball River on the north and the Cheyenne River on the south, is the area comprising in large part what was originally within the Standing Rock and Cheyenne River Indian Reservations. During the spring and early summer of 1909 this region was studied by a number of parties from the U.S. Geological Survey under the general charge of Mr. W. R. Calvert. The geology of this area is comparatively simple, the rocks being very little disturbed and at most comprising not more than four formations. Beginning with the lowest these are the Pierre shale, which is exposed in the valleys of most of the streams, and is overlain without stratigraphic break by the Fox Hills, which is the highest marine formation in the section. Above the Fox Hills, but, as will be shown later, with the intervention in places of a distinct unconformity, comes the Lance formation, above which, but without unconformity or other observed break, is the acknowledged Fort Union.

In the present connection the principal interest naturally centers in the Lance formation, and more particularly as regards its relation with the underlying Fox Hills. Mr. Calvert, who is not only familiar with the area in question but with adjacent areas in North Dakota and Montana where similar conditions obtain, has kindly prepared the following statement:

"Stratigraphic work by field parties in immediate charge of A. L. Beekly, Max A. Pishel, and V. H. Barnett in the Standing Rock and Cheyenne River Indian Reservations of North and South Dakota in 1909 and similar investigation in eastern Montana in 1910 in charge of Max A. Pishel and C. F. Bowen gave opportunity to study the relationship of several formations concerning which discussion has arisen periodically for a number of years, and which is of special interest in view of its direct connection with geologic history at the close of the Cretaceous. The region studied in the Dakotas includes the type locality of the Fox Hills sandstone and is adjacent to the type locality for the Pierre shale. Where the full section of the Fox Hills is present it usually comprises a gradation at the base from the somber shale of the typical Pierre into a more or less massive sandstone. This sandstone member is overlain by 25 feet or more of banded shale overlain in turn by a massive sandstone, constituting what in the field was considered the top member of the Fox Hills. Fossils occur only sparingly in the lower sandstone and in the banded shale, whereas the top sandstone is prolifically fossiliferous, the fossils being found most abundantly at or near the top of that member. Normally overlying this fossiliferous horizon is a sequence of beds entirely dissimilar in lithology from the underlying Fox Hills, and it is concerning these beds that question has arisen relative to their exact position in the geologic column. These strata constitute the Lance formation to which the name 'somber beds' has been applied in various previous publications.

"From the standpoint of lithologic character the term 'somber beds' is very applicable, as the strata are made up chiefly of gray to dark clays and muds with intercalated lenticular sandstone members. There is rapid horizontal alteration in character of material so that a section measured at any one locality does not compare in detail with one measured a short distance away. Carbonaceous zones occur at frequent vertical intervals and the lowest few feet of the formation is almost invariably a lignitic zone.

"As a result of field study by Pishel, Barnett, and the writer, it seems certain that the line between the Fox Hills sandstone and the Lance formation is marked by an unconformity, but the import of that unconformity is of course a matter for the paleontologist rather than for the stratigrapher to decide. However, the evidence gathered by the stratigrapher may possibly have some weight in arriving at a conclusion, and that evidence is here presented.

"The maximum thickness of the Fox Hills sandstone is in the neighborhood of 200 feet, but it was found in the field that this measurement is entirely too great for certain localities. On Worthless Creek, in T16N, R20E, Black Hills Meridian, exposures are especially good and it was here that the most striking example of unconformity between the Fox Hills and Lance formation was observed. On the west side of Worthless Creek Valley; near the line between sections 25 and 26, it was noted that the 'somber beds' of the Lance formation transgressed across the Fox Hills sandstone and that the upper part of the latter formation down to the banded shale member was absent. The unconformity at this locality is angular as well as erosional, for the banded shale dips to the north at a 4-degree angle, whereas the 'somber beds' are horizontal. Within a horizontal distance of 500 feet the 'somber beds' fill a channel eroded in the banded shale of the Fox Hills, so that the total vertical amount of combined transgression and erosion is more than 40 feet. On the opposite side of the valley the total thickness of undoubted Fox Hills is even less, for it appears that the lignitic zone of the 'somber beds' rests on Pierre shale. In any event there is surely less than 25 feet of the Fox Hills present at this place. In view of the fact that the Fox Hills sandstone is normally at least 150 feet thick it would seem that the erosion interval represented is of considerable magnitude, or else that the formation is peculiarly variable in thickness.

"In general the zone along the contact between the Fox Hills sandstone and the Lance formation is poorly exposed in this region, but in the majority of localities where exposures were adequate careful study disclosed evidence that deposition was not continuous from one formation into the other. In a paper[1] on this subject Doctor Stanton admits the occurrence of an unconformity at this horizon in the Dakotas but attaches no particular significance thereto, stating that channeling would normally be expected in the change from marine to land conditions and giving especial weight to the fact that a marine Fox Hills fauna is found commingled with brackish-water types above the unconformity. He states that 'The paleontologic evidence consists of distinctive Fox Hills species belonging to such marine genera as Scaphites, Lunatia, and Tancredia, found directly associated in the same bed with the brackish-water forms and occurring with them in such a way that they must have lived together or near each other and been imbedded at the same time.'

"From the above quotation the inference is plain that Dr. Stanton concludes that the faunal evidence demonstrates with a fair degree of certainty that the unconformity is of minor rather than of major significance. To this conclusion the stratigrapher, is, of course, not qualified to object with authority, but it seems to the writer that the evidence may be looked at from two divergent points of view. Because Fox Hills fossils occur in the lignitic shales at the base of the 'somber beds' and mingled with the brackish water types of the Lance formation is not necessarily proof positive that the various faunas lived at the same time; for if the deposition of the Fox Hills was followed by a definite erosion interval, what is more probable than that in the deposition of succeeding strata fossil shells would be eroded from the marine beds and carried into channels, there to mingle with the then living brackish-water fauna of the Lance formation?

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[1] T. W. Stanton, "Fox Hills Sandstone and Lance Formation ('Ceratops Beds') in South Dakota, North Dakota and Eastern Wyoming," *Am. Jour. Sci.*, XXX (1910), 178.

"That the unconformity at this critical horizon is of more than local significance is borne out in large measure by observations made in the course of an examination of the lignite region in eastern Montana in 1910. Trending southeast from Yellowstone River, 10 miles southwest of Glendive, is an anticline which extends to the South Dakota line and along which the Lance formation is exposed in a zone on either side. Along the axis of this anticline Pierre shale is at the surface in a band several miles in width with a sandstone formation appearing as a zone of outcrop between it and the Lance. Although fossils have not been found in this sandstone it is believed to be the equivalent of the Fox Hills in its type locality. Transition into it from the Pierre shale is perfect, and as in the Dakotas it is overlain by the markedly dissimilar strata composed of alternating lenticular sandstone, somber clays, and carbonaceous zones. In at least two localities in this region the upper surface of the sandstone referred to the Fox Hills is irregular and with every appearance that sedimentation between that formation and the overlying Lance formation was interrupted. These were noted and mapped by Pishel and Bowen and are in Sec. 22, T6N, R60E, Sec. 32, T7N, R61R. The amount of erosion is not great in either case, but in the opinion of the writer the occurrence of an unconformity in this region at appar-

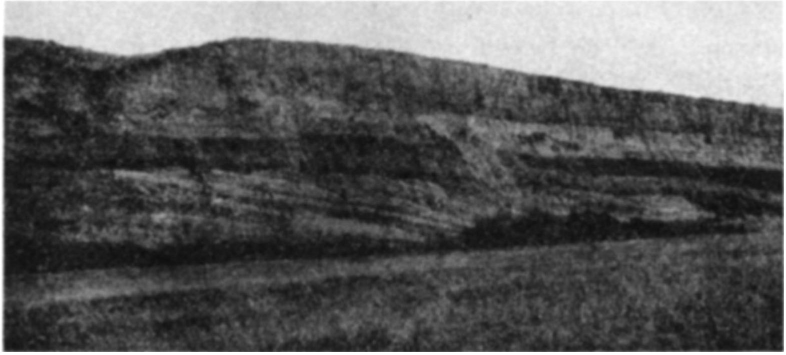


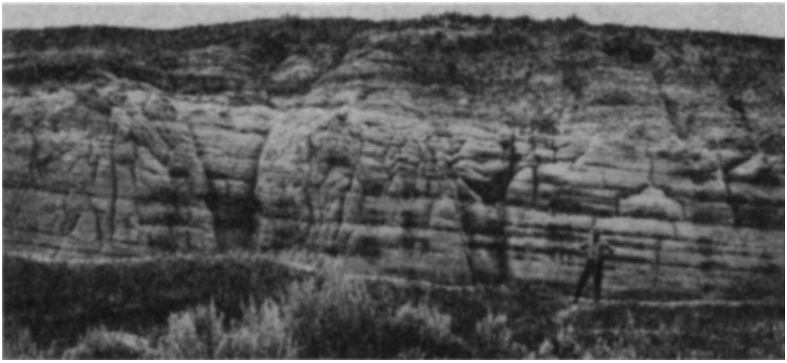
Fig. 1.—South bank Moreau River, near Govert P.O., South Dakota, showing angular unconformity between Lance and underlying beds identified as Fox Hills. Photograph by Barnett.

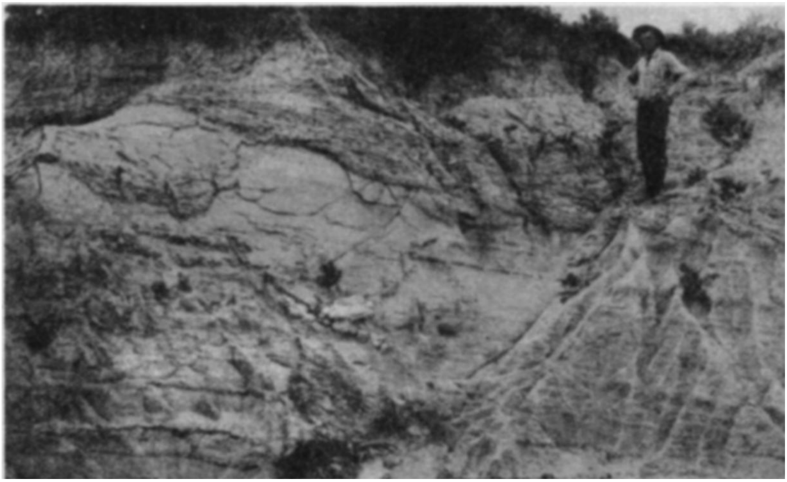
ently the same horizon as that in the Dakotas tends to show that the break has more than local significance."

The observations recorded by Mr. Calvert in the eastern portion of this South Dakota field were supplemented and extended to the western part of the state by Mr. V. H. Barnett in 1910, while making a hasty reconnaissance trip across the country. For instance, on the south bank of the Moreau River, near Govert P.O., in Sec. 21, T15N, R8E, South Dakota, Mr. Barnett found what is perhaps the most marked evidence yet recorded of unconformable relations between beds thought to be Fox Hills and the Lance formation. Mr. Barnett traced the Lance formation continuously from the central part of the state to the point mentioned above, where it was found practically horizontal, while the underlying beds dip to the northwest at an angle of about 10°. These underlying beds appear to be in the stratigraphic position of, and lithologically similar to, beds resting immediately on Pierre shale, at Hoover, about 10 miles southwest, and there is no reasonable doubt regarding their age, but no paleontologic evidence was secured—or sought—at this locality. If the beds are not of Fox Hills age they must be older, which would indicate an unconformity of even greater magnitude than is presumed. Mr. Barnett secured a photograph of this section which he has kindly permitted me to reproduce here as Fig. 1. The full section of the supposed Fox Hills is not exposed at this point, but some distance west, at Castle Rock Butte (T12N., R5E), the following section was measured; Pierre 50 feet; Fox Hills 125 feet; Lance formation 140 feet, the latter overlain by higher Tertiary.

The unconformity spoken of above by Calvert as occurring in Sec. 32, T7N, R61E, in Custer County, Montana, is on the west side of the anticline extending southeast from Glendive. It is clearly shown in the accompanying Figs. 2, 3, the negatives of which were made by Mr. C. F. Bowen, by whose consent they are included here. The Fox Hills with a thickness of about 70 feet dips at an angle of 5°, while the overlying Lance formation is horizontal.

Mr. Calvert's observations concerning the occurrence of the marine Fox Hills invertebrates in the basal members of the Lance formation may be briefly alluded to. It appears that in the hundreds of localities throughout the Dakotas, Wyoming, and Montana at which the contact between Fox Hills and the Lance formation has been examined, only five localities, all within a limited area in South Dakota, have been noted in which the marine Fox Hills invertebrates occur above the acknowledged top of the Fox Hills, where they are often found commingled with certain





FIGS. 2, 3.—Eastern part of Custer County, Montana, showing erosional unconformity between Fox Hills and Lance. Photographs by Bowen.

brackish-water forms. It does not appear that they have ever been found at a greater distance than 12 or 15 feet above the top of the Fox Hills, and since it further appears that in none of the four sections given[1] does the Fox Hills exceed 115 feet in thickness, there is every probability that they were re-deposited in the channeled upper surface of the Fox Hills and that they did not live in association with the brackish-water forms with which they are now found entombed.

The plant collections obtained from the Lance formation by Mr. Calvert and the members of the several parties under his charge show conclusively that the relation of this flora is unmistakably with the Fort Union. In fact with the information at hand regarding distribution it is practically impossible without stratigraphic data to distinguish between the flora of the Lance formation and that of the acknowledged Fort Union. The lists of these collections follow:

[5437]. NW ¼ Sec. 5, T2N, R88W, S. Dakota. North bank of Cannonball River, at McCord coal-bank, 150 feet above base of beds.

Sequoia nordenskiöldi Heer
Thuya interrupta Newb.
Glyptostrobus europaeus Unger
Populus speciosa Newb.
Populus amblyrhyncha Ward
Paliurus colombi ? Heer
Sapindus grandifoliolus Ward
Celastrus alnifolia ? Ward
Juglans sp. ?
2 new forms, gen. ?

[5443]. SW ¼ Sec. 23, T23N, R21E, Black Hills Meridian, 150 feet above base of beds.

Sequoia nordenskiöldi Heer
Leguminosítes arachnioides Lesq.

[5444]. Near ¼ cor. E. side Sec. 13, T22N, R22E. Black Hills Meridian. 125 feet above base of beds.

2 or 3 of same species as unnamed forms from the "somber beds" at Glendive, Montana.

[5430]. Rattlesnake Butte, Cheyenne Indian Reservation, S. Dakota. 100 feet above base of beds.

Glyptostrobus europaeus Newb.
Taxodium occidentale Newb.

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[1] *Am. Jour. Sci.*, XXX (1910), 174-77.

Viburnum marginatum Lesq.
Cornus newberryi Hollick
Salix sp.
Quercus sp.
3 or 4 forms that are identical with unnamed species from Glendive, Montana.

[5422]. Near SE ¼ Sec. 20, T14N, R19E, Black Hills Meridian, S. Dakota. 100 feet or less above base of beds.
Sequoia nordenskiöldi ? Heer
Sequoia langsdorfii Heer
Platanus platanoides ? (Lesq.) Kn.
Viburnum sp. (same as new species from Lance of Converse County, Wyoming).
Lauraceous leaf (same as form found in "somber beds" at Glendive, Montana).

[5431]. SW ¼ Sec. 4, T19N, R18E, S. Dakota. 300 feet above base of beds.
Thuya interrupta Newb.
Populus amblyrhyncha ? Ward
Viburnum elongatum Ward
Viburnum sp. ?
Grewiopsis whitei ? Ward

[5432]. SE ¼ Sec. 25, T20N, R18E, S. Dakota. 300 feet above base of beds.
Sequoia nordenskiöldi ? Heer
Zizyphus cf. Z. hyperboreus Heer
Populus ? sp.
Platanus ? sp.

[5433]. Sec. 33, T20N, R20E, S. Dakota. 150 feet above base of beds.
Ginkgo adiantoides Heer
Platanus raynoldsii ? Newb.
Sapindus grandifoliolus ? Ward
Viburnum (apparently same as unnamed species from Lance of Converse County, Wyoming).

[5434]. SE ¼ Sec. 12, T19N, R24E, S. Dakota. Base of beds.
3 fragmentary leaves, apparently same horizon as No. 5436.

[5436]. NE cor. Sec. 7, T17N, R24E, S. Dakota. Base of beds.
Platanus haydenii Newb.
Viburnum elongatum Ward
Viburnum marginatum ? Lesq.
Sapindus grandifoliolus ? Ward
Dombeyopsis sp.
Polygonum ? sp.
Lauraceous leaf like that of Glendive, Montana
2 species same as unnamed form from Glendive

[5423]. South of Moreau River about 7 miles above Thunder Butte P.O., S. Dakota.
Sec. 35, T14N, R19E. Lower 4 feet of Lance formation.
Thuya interrupta Newb.
Sequoia nordenskiöldi Heer
Sequoia acuminata ? Lesq.
Populus cuneata Newb.
Viburnum marginatum ? Lesq.
Leguminosites ? n. sp.
Cyperacites sp.
Monocotyledon—new

It needs but a glance at the above lists to show how preponderating is the Fort Union facies.

CONVERSE COUNTY, WYOMING

Although Converse County, Wyoming, is the type locality for the Lance formation, and has been visited again and again by geologists and paleontologists, it is still a perennial source of discussion and difference of opinion. From the first, difficulty has been experienced in drawing the line between the highest marine formation—the Fox Hills—and the overlying dinosaur-bearing beds. The Fox Hills was estimated by Hatcher to have a thickness of 500 feet, and consists of an alternating series of sandstones and shales, with massive sandstones at the top which contain numerous large concretions and a rich marine fauna of characteristic Fox Hills species. The upper line was drawn somewhat arbitrarily at a six-inch band of hard sandstone which was thought to separate the fossil-bearing Fox Hills sandstone below from similar but supposedly non-fossiliferous sandstones above. When Dr. Stanton and I visited this region in 1896 we failed to secure evidence for changing the top line of the Fox Hills as established by Hatcher, though we did find four species of brackish-water invertebrates in clays above a forty-foot bed of massive sandstone over 400 feet above the highest fossiliferous Fox Hills horizon in that particular section.

So the question rested until 1909, when Messrs. M. R. Campbell, T. W. Stanton, and R. W. Stone spent nearly a week in the region. Their principal contribution to the knowledge of the stratigraphy of the area was, according to Stanton,[1] "the discovery that the marine Fox Hills deposits extend about 400 feet higher than had previously been determined, and that non-marine coal-forming conditions were temporarily inaugurated here before the close of Fox Hills time." If Hatcher's estimate of the thickness of the beds assigned by him to the Fox Hills was anywhere near correct this "discovery" would seem to increase the total thickness to about 900 feet, yet nowhere in the paper mentioned is a thickness greater than 400 or 500 feet claimed for it. This appears difficult to explain unless the lower as well as the upper limit of the formation has been changed.

A number of sections are given by Dr. Stanton, in one of which at least, namely that on Buck Creek, the top of the Fox Hills appears to have been fixed by the presence of the plant *Halymenites major*. The thickness of the Fox Hills in this section is given as 505 feet, though the highest horizon at which marine Fox Hills invertebrates occur is about 180 feet below the top.

In the section made on the divide between Lance and Buck Creeks the Fox Hills is said to have a thickness of 445 feet, though the lower member of the section only (30 feet above the Pierre shale) is indicated as containing a Fox Hills fauna.

The section made on the south side of the Cheyenne River at the mouth of Lance Creek shows a thickness of 405 feet of Fox Hills above the Pierre, but the highest point in the section at which marine Fox Hills invertebrates were found is over 100 feet below the top. It further appears from this section that the upper four members, aggregating 115 feet in thickness, contain carbonaceous and lignitic shales as well as fragments of dinosaur bone and brackish-water invertebrates, certain of which are the same as those found in, and there said to indicate the Laramie age of, the 400 feet of beds already mentioned as reported by Stanton and Knowlton above the typical marine Fox Hills.[2] To the writer it seems altogether more probable that the four upper members of this section belong to the Lance formation and not to the Fox Hills, and it appears that this was the view at first entertained by Dr.

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[1] *Am. Jour. Sci.*, XXX (1910), 184.

[2] *Bull. Geol. Soc. Am.*, VIII (1897), 130.

Stanton, who says,[1] "When studying the section it was believed that the upper four members belong to the Lance formation, but afterward when comparison was made with sections of the south end of the field it seemed more possible that all the beds examined here belong to the Fox Hills." If this portion of the section is placed in the Lance formation, where it certainly appears to belong, the thickness of the Fox Hills in the section is reduced to 285 feet, or but little more than half of the maximum thickness assigned to beds of this age in the Converse County region. While this evidence may not be considered conclusive, it must at least be admitted that it strongly suggests the possibility that even here, as in the areas already discussed in the Dakotas and Montana, the Fox Hills is of variable thickness, due to the erosion of the upper portions before the deposition of the Lance formation.

It is to be admitted, however, that all who have studied the Converse County areas have had, and still have, difficulty in fixing the upper line of the Fox Hills, but in this connection it is to be pointed out that while many students have visited or collected in the region, it still awaits the careful, painstaking study that has been given other fields, such, for instance, as the areas in the Dakotas and Eastern Montana, which have been described by Mr. Calvert. And in this connection it may be mentioned that although in Converse County the exact location and extent of the unconformity between Fox Hills and Lance is not definitely known, the time interval is undoubtedly indicated, since 150 miles to the southeast (i.e., opposite the mouth of the Medicine Bow River) the same dinosaur-bearing beds are above an unconformity which separates them from 6,000 feet of unquestioned "Laramie," while 100 miles to the east in the Dakotas, the Lance formation rests on an uneven surface which in some cases represents the removal of practically the whole thickness of the Fox Hills of the region.

As a possible explanation of the difficulty experienced in detecting the presence of the unconformity between the Fox Hills and overlying Lance formation in this area, the following facts may be offered: the localities in Eastern Montana and Western South Dakota where the examples of the distinct angular and erosional unconformity are so well exhibited are all adjacent to the anticlinal uplift which Calvert has shown extends southeast from the vicinity of Glendive, Montana, to the western line of the Dakotas. Here the uplift tilted the beds and accelerated the erosion, while in the flat country to the westward in Converse County and adjacent areas, the erosion of the Fox Hills was relatively uniform, and when the Lance formation was later laid down over this surface the unconformable relations are difficult of detection. But as Cross long ago stated:[1] "The visible conformity between the Ceratops beds and Fox Hills in Converse County cannot be accepted, contrary to other evidence, as proving the former to have been deposited in the epoch next succeeding the Fox Hills."

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[1] *Am. Jour. Sci.*, XXX (1910), 185.

UPPER LIMIT OF THE LANCE FORMATION

In my original paper on the Lance formation ("Ceratops beds") I stated that everywhere throughout the vast region studied it was found conformably overlain by the acknowledged "yellow" Fort Union, adding that "of the many workers who have observed the field relations at hundreds of points, not one, so far as known to the writer, has recorded the presence of unconformity between them." Field work during the past two seasons has confirmed this statement in every particular, and there is yet to be observed a single locality at which unconformable relations have been even suspected. Hence it seems to have been demonstrated that sedimentation from one to the other was continuous and uninterrupted.

At the time the original paper was published it was thought that the Lance formation and the acknowledged Fort Union (the lower and upper members of the Fort Union as they were there called) might usually be separated on lithologic grounds, the lower being generally dark and somber-colored and the upper usually yellow. Subsequent investigation, however, has failed to confirm this, for while in individual sections, or even within limited areas, a provisional lithologic separation may often be made, when regional studies were undertaken it was found that the lithologic difference was so variable within short distances as to be wholly unreliable. For instance when a coal-bed that occurred near the top of the so-called somber-colored Lance formation was traced accurately for only a few miles it was found that the position of the dark-colored and the yellow beds varied as much as 300 feet, that is, at one point, the coal-bed might be 150 feet down in the somber-colored portion, and at another, an equal distance up in the yellow beds. It may therefore be confidently stated that the Lance formation and acknowledged Fort Union cannot be separated formationally on either structural or lithologic grounds, though in general the lower beds are on the whole prevailingly somber in color, while the upper beds are prevailingly yellow.

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[1] *U.S. Geol. Survey, Mon. 27* (1896), 236.

MAGNITUDE OF UNCONFORMITY AND BOUNDARY BETWEEN CRETACEOUS AND TERTIARY

Having demonstrated the existence of unconformable relations between the Lance formation and the underlying formations, the question naturally arises as to the magnitude of this discordance. By some it is claimed that it is merely local and is not more important than other breaks said to occur at various intervals in the Lance formation, and the doubt is expressed whether, even if the unconformity is present, any great amount of erosion is indicated.

The wide area over which its existence has now been demonstrated certainly removes it from the category of "local" happenings, and the uniformity of its occurrence beneath the Lance formation is sufficient indication of its importance over any that have been thus far even apparently indicated within the formation. Now as to its magnitude. It has been shown that in Carbon County, Wyoming, the Lance formation is not only above the full thickness of the "Laramie" (6,000 feet) but is separated from it by an unconformity that Veatch states is fully 20,000 feet, and moreover this unconformity is in the same position as regards the Laramie as that in the Denver Basin of Colorado, which, according to Cross, has involved the removal of from 12,000 to 15,000 feet of strata between the Laramie and overlying formations. It is possible that the figures given by Cross and Veatch may be too high, but even so, the unconformity is undoubtedly one of importance, and this would seem to dispose of the contention that the Lance, Arapahoe and Denver formations may be mere "phases of the Laramie." Whether the Laramie and various post-Laramie beds were deposited and later removed throughout the Dakotas, Montana, and Wyoming, is not at present known, but certain it is that the unconformity at the base of the Lance formation represents the time interval during which in other areas they were laid down and subsequently removed in whole or in part. Therefore, in the opinion of the writer, this unconformity is an important one and must be so recognized in American geology.

Since it has been demonstrated that the Lance formation is so inseparably associated with the Fort Union—that is, without a trace of an unconformity—and is separated from the underlying formations by an unconformity of such extent, this point becomes more clearly than ever the logical point at which to draw the line between Cretaceous and Tertiary. In establishing this line the stratigraphic, lithologic, and paleobotanical criteria are believed to be more competent than any other evidence thus far brought forward.